H. C. CALDWELL.

TRANSFORMER SYSTEM.

APPLICATION FILED SEPT. 9, 1910.

1,008,293.

Patented Nov. 7, 1911.

2 SHEETS—SHEET 1.

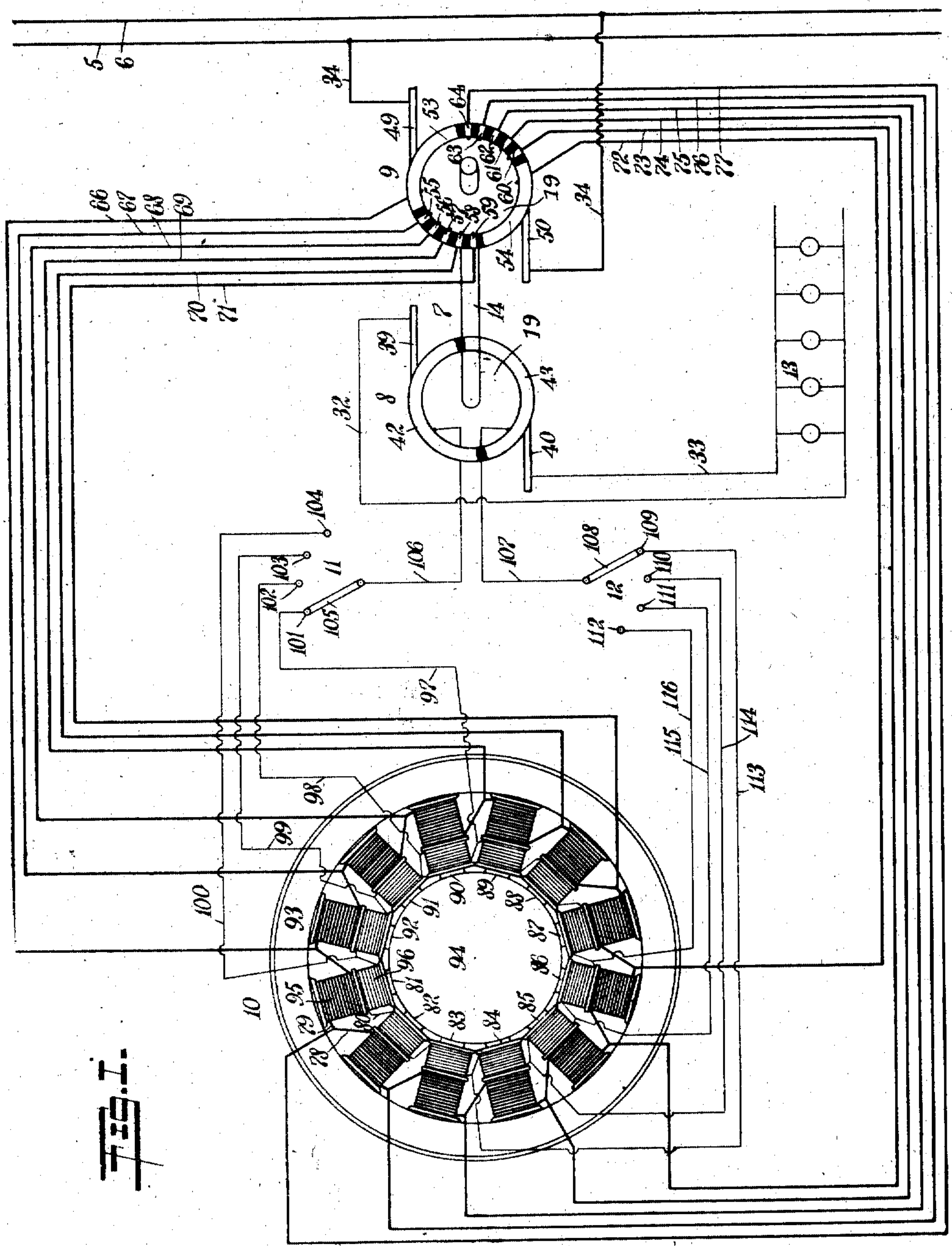

FIG. 1.

WITNESSES

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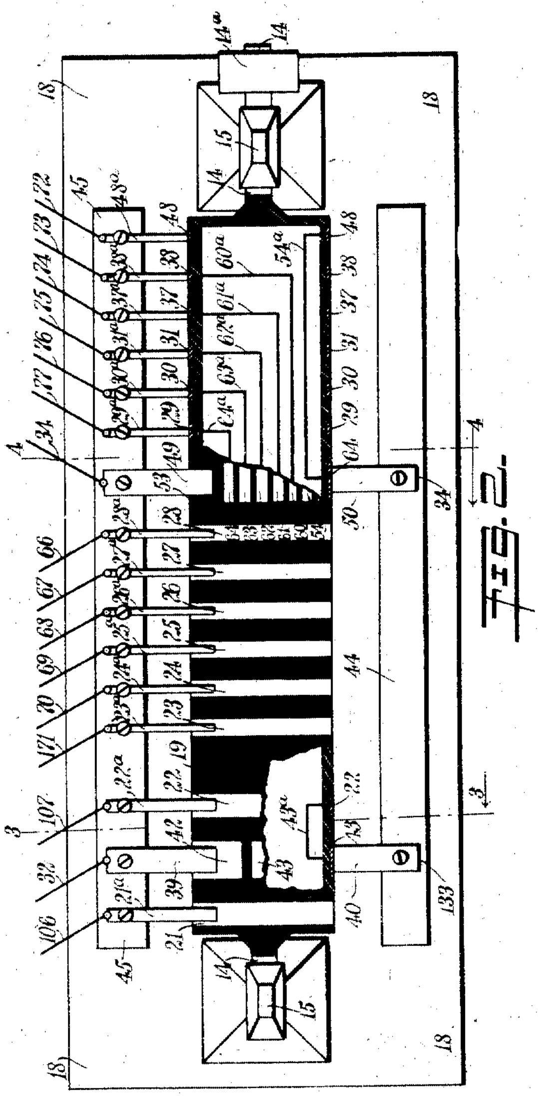

FIG. 2.

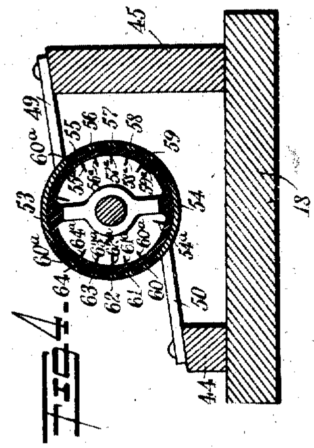

FIG. 4.

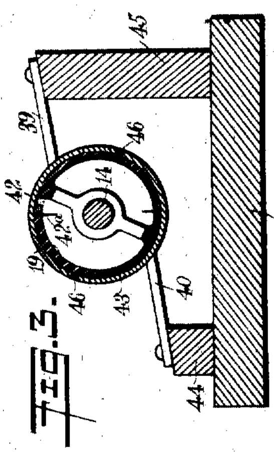

FIG. 3.

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TRANSFORMER SYSTEM.

1,008,293. Specification of Letters Patent. Patented Nov. 7, 1911.

Application filed September 9, 1910. Serial No. 581,306.

To all whom it may concern:

Be it known that I, Henry C. Caldwell, a citizen of the United States, and a resident of Fort Mills, Corregidor, Philippine Islands, have invented a new and Improved Transformer System, of which the following is a full, clear, and exact description.

My invention relates to transformer systems, my more particular purpose being to provide such a system in which a peculiar advantage is taken of the fact that time is required for the magnetic field to flow, under the influence of variations in the exciting electric current.

My invention further contemplates various improvements in the manner of connecting up the various transformer units and in the distribution of both exciting and induced electric currents employed in connection with such units.

Reference is to be had to the accompanying drawings forming a part of this specification, in which similar characters of reference indicate corresponding parts in all the figures.

Figure 1 is a diagram showing my transformer system complete; Fig. 2 is a section through the commutator mechanism which, in a large measure, controls the distribution of both exciting and induced currents; Fig. 3 is a section on the line 3—3 of Fig. 2, looking in the direction of the arrow; and Fig. 4 is a section on the line 4—4 of Fig. 2, looking in the direction of the arrow.

My system is supplied with direct currents from wires 5, 6. At 7 (Fig. 1) is the commutator mechanism, which includes a pair of rotary sectors 8, used for rectifying the induced currents, and also a group 9 of rotary sectors used for distributing the exciting currents to the transformer units which are shown as a group at 10. At 11, 12, are hand switches for controlling, within certain limits, the character of the induced currents. By aid of these hand switches the voltage of the induced currents may be varied at will. At 13, is a group of incandescent lamps to be supplied, I will say, with direct current. A revoluble shaft 14 is mounted in bearings 15, and is adapted to be turned at a very high rate of speed. The bearings 15 are supported upon bases 16, 17, which rest upon a foundation 18. See Fig. 2. A driving pulley 14^a is secured upon the shaft 14, for actuating the same. A cylindrical drum 19 is secured rigidly upon the shaft 14, and is adapted to turn therewith. Mounted rigidly upon the exterior of this drum and sunken into the outer surface thereof are rings 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 37, 38, 48, the pair of sectors 42, 43, at 8, and also the group of sectors 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, at 9. Bearing upon these rings and slidably engaging the same, are a number of stationary brushes, 21^a, 22^a, 23^a, 24^a, 25^a, 26^a, 27^a, 28^a, 29^a, 30^a, 31^a, 37^a, 38^a, 39, 40, 48^a, 49, 50. The brushes 21^a, 22^a, etc., are mounted at right angles to the axis of rotation of the drum 19 upon supports 44 and 45, which are secured directly to base 18, the brushes 21^a, 39, 40, 22^a, 23^a, 24^a, 25^a, 26^a, 27^a, 28^a, 49, 50, 30^a, 31^a, 37^a, 38^a and 48^a being so adjusted that they engage the rings and sector groups as they revolve with the drum 19.

The sector portion 8 comprises two sectors 42, 43 (see Fig. 3), each having substantially the form of a semi-ring and being so positioned as to be engaged by the brushes 39 and 40, when revolving. The sector 42 is connected with ring 21 by a wire 42^a passing between them on the interior of the drum, and the sector 43 is connected with the ring 22 by a wire 43^a, in the same manner. Filled in between the sectors 42, 43, are portions 46 of insulating material, these portions following generally the contour of the sectors, as will be understood from Figs. 3 and 4.

The sector portion 9 comprises two large sectors 53 and 54, disposed diametrically opposite each other, and also a number of smaller sectors 55, 56, 57, 58, 59, 60, 61, 62, 63, 64. These sectors are separated from each other by ribs 60^a of insulating material. These sectors 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, are connected by wires 55^a, 56^a, 57^a, 58^a, 59^a, 60^a, 61^a, 62^a, 63^a and 64^a, passing on the interior of the drum 19 to rings 28, 48, 27, 26, 25, 24, 23, 38, 37, 31, 30 and 29, respectively.

Connected with the brushes 23^a, 24^a, 25^a, 26^a, 27^a, 28^a, are wires 171, 70, 69, 68, 67 and 66. Connected similarly with the brushes 29^a, 30^a, 31^a, 37^a, 38^a and 48^a, are wires 77, 76, 75, 74, 73, 72. Each of the wires 66 to 77 inclusive, is connected with two branching wires 78, 79, these wires 78, 79, together with wires 80, being connected with transformer units 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92. These transformer units are practically so many stationary transformers. For convenience they are mounted in an iron ring 93, and disposed centrally within this ring is a disk 94, also of iron. The ring 93 and the disk 94 have considerable inductance, and on this account the transformer units are slow to lose their magnetism. Each transformer unit comprises a primary winding 95 and a secondary winding 96. The various secondary windings are connected serially together by aid of the wires 80, above mentioned. The various primary windings 95 are similarly connected in series by aid of the connecting wires 78, 79. The primary windings are so arranged that when a current is sent through any one of the wires 66 to 77 inclusive, this current divides, one half of it passing through six primary windings and the other half of it passing in the opposite direction through the other six primary windings. This action is more fully described below. A number of wires 97, 98, 99, 100, are severally connected with the secondary circuit at points between the consecutive pairs of secondary windings. These wires 97, 98, 99, 100, lead to stationary contact buttons 101, 102, 103, 104, in the hand switch 11. This hand switch is provided with an arm 105 movable by hand and adapted to engage any one of the contact buttons just mentioned. A wire 106 is connected with the arm 105, and also with the brush 21ª, bearing upon ring 21 which is connected with sector 42, which, as above explained revolves rapidly. A wire 107 is similarly connected with the brush 22ª, ring 22 and sector 43, which likewise revolves.

The switch 12 is provided with an arm 108 movable by hand, and also with contact buttons 109, 110, 111, 112. Connected with the latter are wires 113, 114, 115, 116, which lead to the circuit, being connected therewith at points between consecutive pairs of the secondary windings, as shown at the left of Fig. 1.

The operation of my device is as follows: I will suppose that a direct current is to be transformed so as to produce direct currents of low voltage, and that the latter are to be used for illuminating the group 13 of incandescent lamps. I will suppose, further, that the operator wishes, within suitable limits, to regulate the voltage of the direct currents from time to time. The parts being connected as above described, and a high speed being given to the revoluble shaft 14, by aid of the pulley 14ª, the drum 19 carrying the various rings and sectors is turned rapidly, and the sectors, of course, sweep around making and breaking engagement with the brushes 39, 40, 49, 50, but each ring is continually in contact with the brush which bears upon it. It might seem at first glance that in doing this, there might be generated, owing to difference in proportions of the various sectors, distinct groups of alternating currents of exceedingly high frequency. Since, however, the transformer units have great inductance, they do not lose their magnetism with sufficient rapidity to permit this result. Bearing this fact in mind, I will now analyze the action which takes place. Suppose, that, at a particular moment during the rotation of the shaft 14, the drum (see Fig. 1) happens for an instant to be in the position indicated in this figure. The sectors 53, 54, owing to their great length, are in engagement with the brushes 49, 50, for a relatively long period of time. The result is that the various magnetic parts now affected by the current have sufficient time to build up their magnetic fields to a maximum limit. The following is a circuit whereby this is done: wire 5, wire 34, brush 49, sector 53 to ring 28 (see Fig. 2) brush 28ª, wire 66 to transformer mechanism 10, where the current divides, one-half of it passing in one direction in series through six of the primary windings 95, the other half of it passing through the remaining six of the primary windings, the two portions of the current now joining together and passing through the wire 72 to brush 48ª, ring 48, wire 54ª, sector 54, brush 50. Thence the current passes through wire 34 to the wire 6 thence to power house and back to the wire 5. It will be noted that six of the primary windings are now of one polarity and six of the opposite polarity, and that all of the magnetic fields are of maximum strength, this being due to the fact that, owing to the length of the sectors 53, 54, the current flows for a sufficient (though, of course, infinitesimally short) period of time, to allow the fields to thus build up. If now at this instant the influencing current traversing all of the coils is suddenly changed in its direction, the magnetism of the iron will drop to zero and build up to a maximum in the opposite direction. If this change in the direction of the current is sudden enough, it will assist the magnetism in all of the units in dropping to zero. This reversal of the current is obtained and without breaking the circuit, by the use of the short sectors, which remain in contact with the brushes but a very small fraction of the time of each half revolution. As the shaft 14 turns a little farther, the brush 49 overlaps the insulation and engages the sector 64 before breaking contact with sector 53, the brush 50 meanwhile engaging the sector 59. The shaft turns farther, brush 49 is disengaged from sector 53, and brush 50 is disengaged from sector 54. They are now in contact with sectors 64, 59. A circuit is thus completed, in tracing which I will, for convenience, omit reference to the various mechanical details shown in Fig. 2. This circuit is as follows: wires 5, 34, brush 49, sector 64, wire 77 to the transformer unit; here the current divides, one-half of it passing in one direction through six of the primary windings, and the other half passing in the opposite direction through the other six primary windings. It will be noted, however, that while the number of primary windings thus energized is identical with the number first energized, the conditions have changed slightly, because in two of these windings diametrically opposite each other the direction of the current has changed. The result is that two magnetic fields which had been built up are now being torn down and re-built in the opposite direction. The total influence of all of the fields is therefore, for the moment, less than at first,—for, although the reversal of the current in the two coils is helping the magnetism to drop to zero, the magnetism itself is generating a counter E. M. F. in the coils, which affects the whole circuit. The revoluble drum turns still farther, the sector 63 makes contact with brush 49, and at the same instant the sector 58 makes contact with brush 50 and the current in two more of the coils is reversed. An electromotive force which makes an addition to that being generated by the first reversal, is caused to flow against the influencing current also. The total effect of the magnetic field is thus impaired still more. There are now four units with their magnetism changing, that of the first reversals being farther advanced or changed than that of the second. Next the sector 62 makes contact with brush 49, the sector 57 similarly making contact with the brush 50. The supply current is again shifted to another advanced position of the primary windings and is reversed in two more of the units. The magnetic field changing through these coils generates a counter E. M. F. in like manner. Since the change in the first coils has not had time to be completed owing to the rapid frequency of the reversals, they are still generating a counter E. M. F. and each succeeding E. M. F. is an addition to that already operating. This process is continued until the last of the smaller sectors—to-wit, the two sectors numbered 60 and 55, have been brought into contact with the brushes 49, 50 and the field affected accordingly. The magnetism is now changing in ten of the units and the counter E. M. F. is almost as strong as the influencing current. Next the long sectors 54, 53, are in contact with brushes 49, 50, and the current is reversed in all of the units. These sectors keep the currents impressed upon terminals of the units diametrically opposite each other, until the desired magnetizing effect is secured. The aggregate result is that, during each half turn of the shaft 14, the aggregate magnetic field of the transformer system 10, beginning, we will say, at a maximum, is reduced gradually to a minimum. During the next succeeding half turn of the shaft 14, the process above described is repeated. The field is first built up to a maximum and then reduced to a minimum. Each complete revolution of the shaft 14, therefore, means building up the field twice at opposite polarities and reducing the field twice. As a consequence, the various secondary windings 96, being acted upon inductively by the primary windings and by the masses of iron in their vicinity, generate induced currents, which are, of course, alternating in character, there being one complete cycle, (two alternations) of these currents to each turn of the shaft 14. With the hand switches 11, 12, arranged as indicated, the circuit made by the induced currents may be traced as follows: secondary windings 96 (which are in series with each other and practically form a ring) wire 97, contact button 101, arm 105, wire 106, brush 21^a, ring 21, wire 42^a to sector 42, brush 39, wire 32, group 13 of lamps, wire 33, brush 40, sector 43, wire 43^a to ring 22, brush 22^a, wire 107, switch arm 108, button 109, wire 113, back to the ring of secondary windings. The currents thus generated by induction in the secondary windings and following the circuit just traced are, when generated, alternating currents. By passing through the stationary brushes 21^a, 22^a, 39, 40, and rotating rectifying sectors 42, 43, however, these currents are duly rectified and pass as direct currents through the lamps 13.

The action of the secondary circuit, as a whole, may perhaps be better understood by bearing in mind that while the primary windings and the secondary windings are stationary, yet the magnetic field set up by aid of the primary windings is not fixed but alternating; also that this field gradually waxes and wanes in its strength which never becomes *nil;* and that during one complete cycle of this alternating field the strength of the latter is twice carried to a maximum and twice reduced to a minimum, the change in strength being not abrupt but gradual, owing to the fact that the field, because of the quantity of iron associated with it possesses a lagging effect, and does not change in value instantaneously, as an electric current does. Such being the case, it follows that in the secondary circuit there are induced alternating currents of one complete cycle to every two reversals of the field, and that these alternating currents may have the approximate form usually represented by fewer sine waves. By disconnecting the wires 106, 107, from the rectifying commutator mechanism, these wires may be used for supplying alternating current. Since the magnetic field varies as above described, and since in so doing, it affects all points alike, it follows that each of the secondary coils have induced in them a like voltage and that any of the coils joined together makes an addition of the voltages. Thus by connecting various wires at different points in the circle made up of secondary windings these respective wires may be energized by currents of different voltages. Moreover, by aid of the hand switches, any two of the wires just mentioned may be virtually brought together, so as to select from different portions of the ring of secondary windings currents of any desired voltage. This is why I employ the hand switches 11, 12 and the wires associated with them. By moving the switch arms 105, 108 to different buttons, the voltage of the induced currents may be varied within suitable limits. Indeed, the voltage may at will be graduated practically from zero to a maximum. With the switches 11, 12, arranged as indicated in Fig. 1, the voltage is at a minimum. With the switch arm 105 moved over to the contact button 104 and the switch arm 108 in contact with the button 112, the induced currents will be at a maximum. This is because when a primary current flows, I will say, through the wire 66 and divides so that one-half of it passes down through the primary windings at the right of the transformer mechanism, and the other half passes down through the windings at the left of the transformer mechanism, one-half of the secondary windings at the right of the transformer mechanism neutralize the work of the other half of the secondary windings at the right of this mechanism, and a similar statement is true of the secondary windings at the left of the transformer mechanism. Hence, with the switch arms 105, 108 in the positions indicated, there is a neutralization of the current in one secondary winding by a current in another secondary winding.

In following the action of the system as above described, it is necessary to bear constantly in mind that where large masses of iron are in close proximity to magnets, so as to affect the magnetic field, a perceptible moment of time is required to reverse the polarity of the field, or of any distinct portion thereof, and a still longer period of time is required to reverse this polarity and after its reversal bring it up to a maximum. It should also be borne in mind that the speed given to the machine may, within proper limits, have quite an effect upon the character and strength of the currents produced. It should further be borne in mind that the proportions of the various parts should be selected with a view to carrying out the foregoing result. If, however, the various parts are properly proportioned and a high speed selected suitable for these proportions, and the revoluble shaft is turned at a constant rate of speed, the system can not only be used as described, but may be employed for a variety of distinct purposes.

The principle of the invention may perhaps be understood more readily by bearing in mind that for every half revolution of the drum the magnetizing current has been reversed instantaneously in all of the primary windings, and the pressure is then kept upon definite terminals until the slow changing magnetism in the iron reaches full strength, when the magnetizing current is again reversed by the next half revolution: the net result being that a direct current is made to alternate in a system of transformers as an alternating current would, the magnetism thereby generated, inducing currents in secondary windings, as above explained.

While for convenience I show the transformer units as arranged in a circle, this is a matter of no consequence, as obviously, being stationary they may be arranged in any desired relative position.

The apparatus may be used in practice for raising or lowering the potential of a given current, or to change direct current into alternating current. It may be of service for transmission of power over great distances, charging storage batteries, and also in electro-plating, electric welding, therapeutics, X-ray work, and wireless telegraphy. In general, it is desirable to supply the apparatus with direct currents of high potential.

Having thus described my invention, I claim as new and desire to secure by Letters Patent:

1. In a transformer system, the combination of a number of transformer units, means for shifting currents from one of said units to another for the purpose of building up magnetic fields associated with said units, mechanism for varying the strength of said currents thus shifted, thereby producing variations in said magnetic fields, a plurality of independent connections to different transformer units for the purpose of drawing off induced currents of different voltages, and means controllable at will for selectively connecting different pairs of said connections in order to draw therefrom said currents of different voltages.

2. In a transformer system, the combination of a plurality of transformer units, each having a secondary winding and a primary winding, a source of electricity for supplying currents to said primary windings, connections for dividing said currents so as to pass one half thereof through some of said

primary windings, and the other half through others of said primary windings, and means for shifting the point of application of said currents thus divided so as to produce an alternating field, and a secondary circuit acted upon inductively by said field.

In testimony whereof I have signed my name to this specification in the presence of two subscribing witnesses.

HENRY C. CALDWELL.

Witnesses:

MURRAY B. DILLEY,

ANDREW J. LAWRENCE.